Gamma-Ray Bursts as extreme probes of Cosmic Dawn

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(GRB working group for Gamma-Ray SIG roadmap)

What motivates gamma-ray observations of GRBs?

- Understanding the physics of GRBs and jetted relativistic outflows
- GRBs as a tool for cosmology: emphasis of this presentation
- GRBs as beacons for multi-messenger astronomy

Gamma-Ray Bursts are a signature of stellar death

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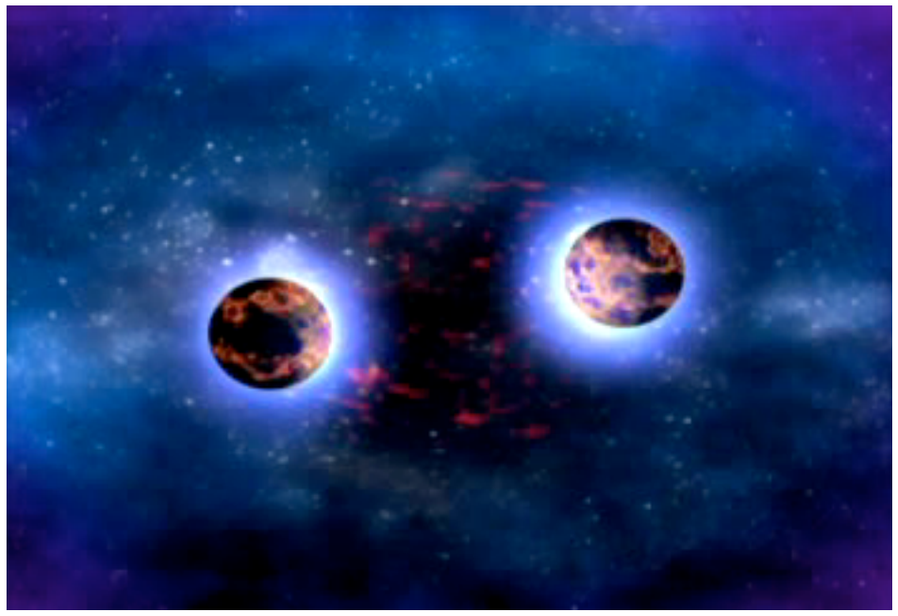

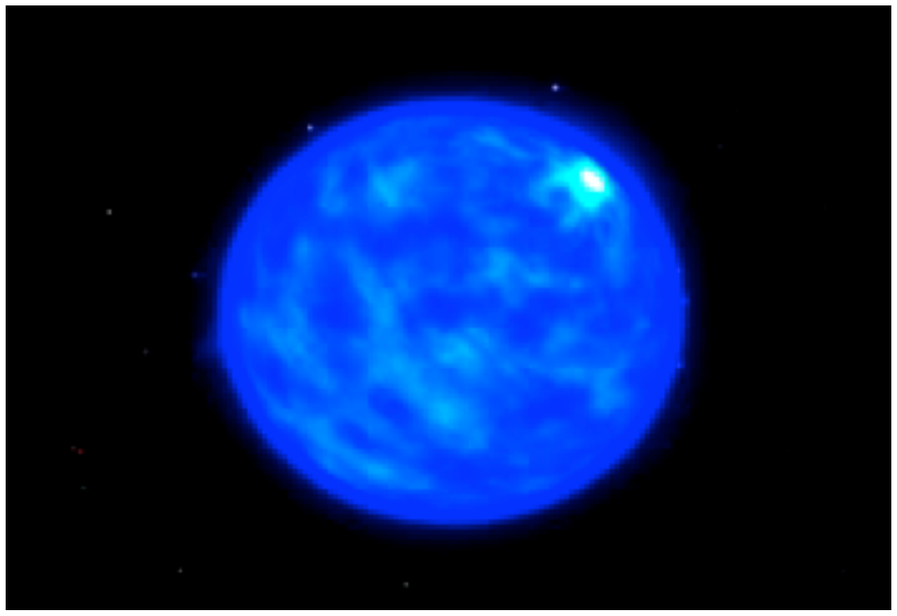

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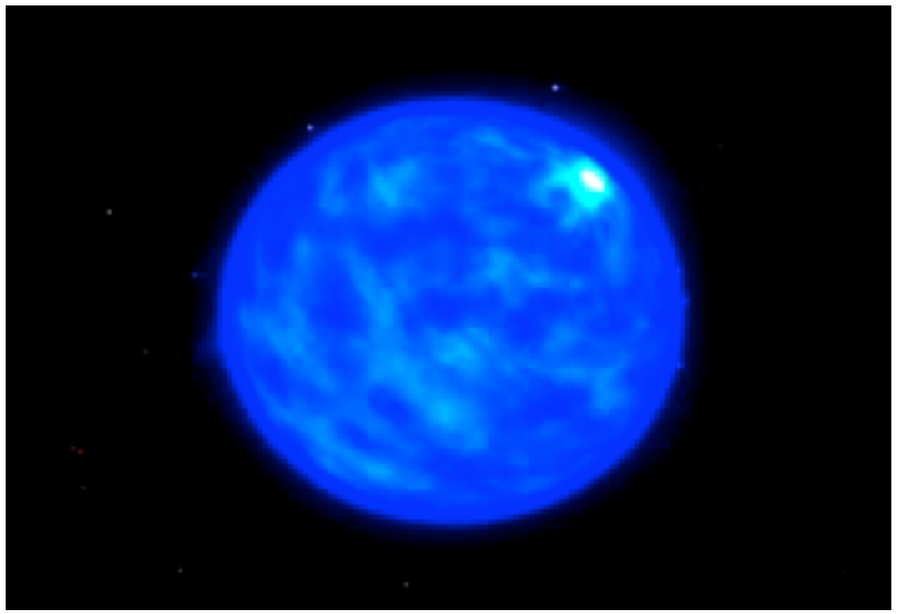

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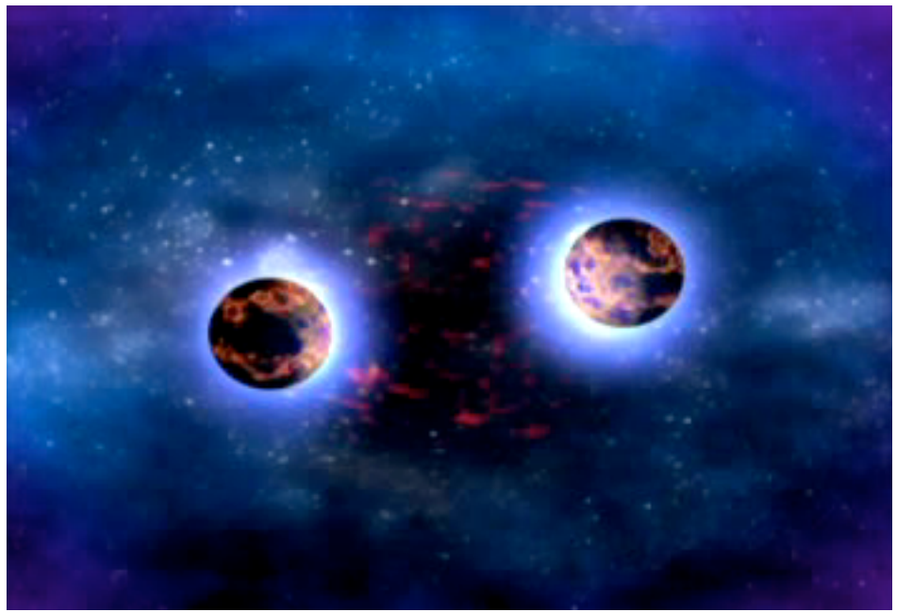
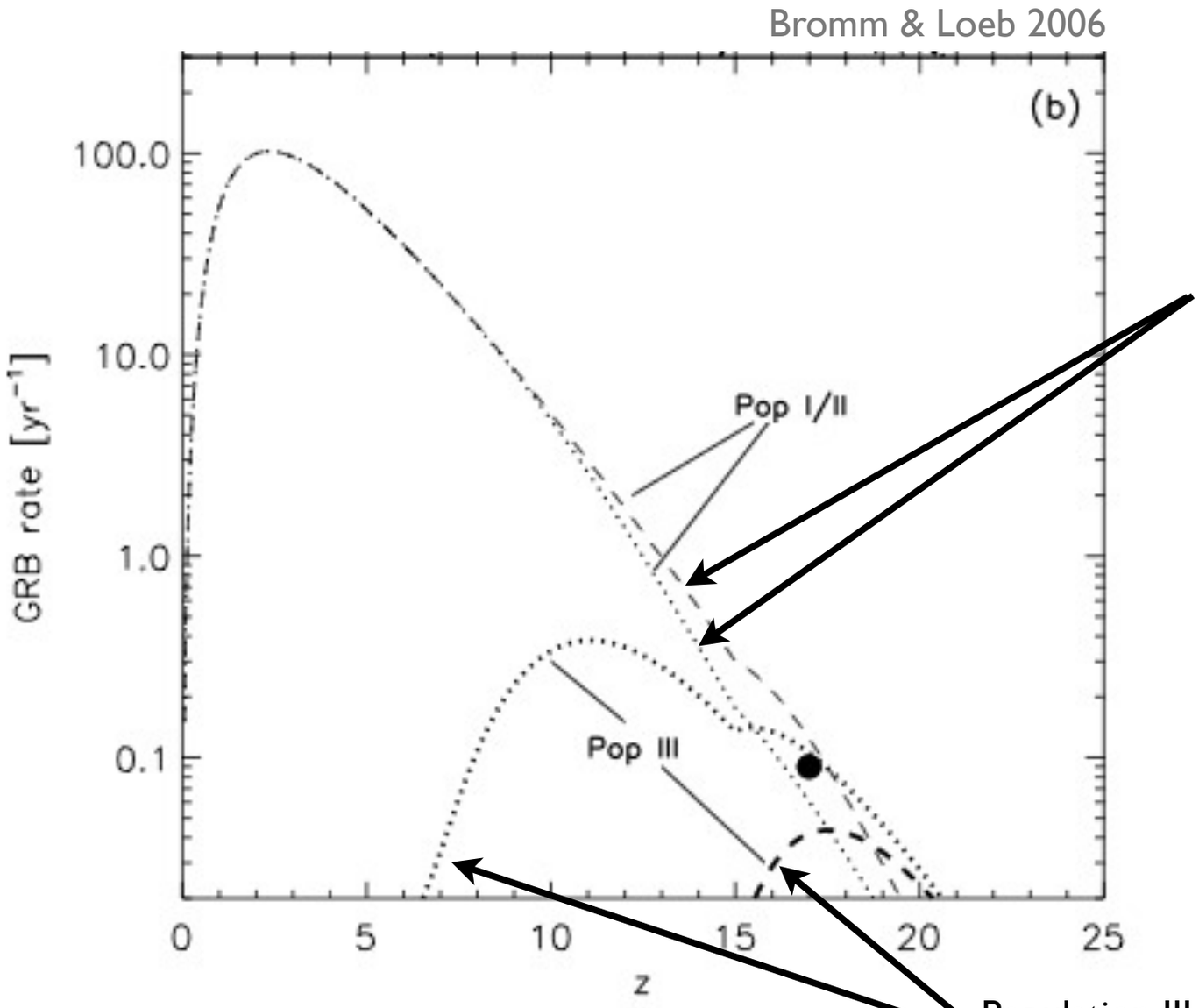


Expected GRB detection rate as a function of redshift for NASA's Swift mission assuming GRBs follow star formation rate suggests GRBs detectable at cosmic dawn.

Bromm & Loeb 2006



Population I/II stars assuming weak chemical feedback (dotted) or strong chemical feedback (dashed)

Population III stars assuming weak chemical feedback (dotted) or strong chemical feedback (dashed)

Can Pop III stars form GRBs and do they look like Pop I/II GRBs?

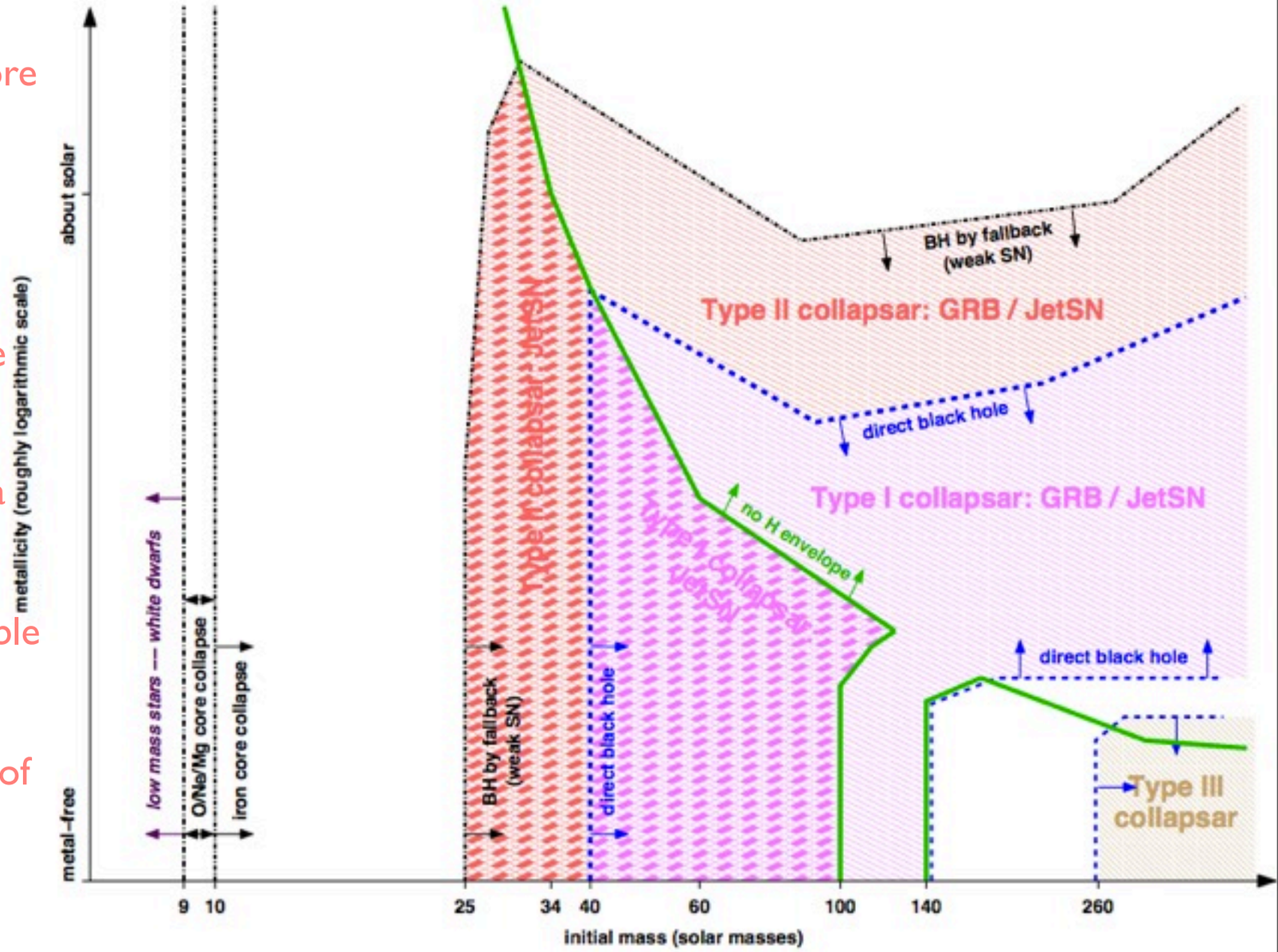
Massive enough for BH formation? Yes! More massive than Pop I/II at life end.

Enough angular momentum? Yes (chemical mixing, Stacy, Bromm, & Loeb 2010)

Can they get rid of H envelope? Yes, the more massive ones (but not too massive), or those with a companion (later Pop III), or envelope may be pierced by magnetic jets (Suwa & Ioka 2010).

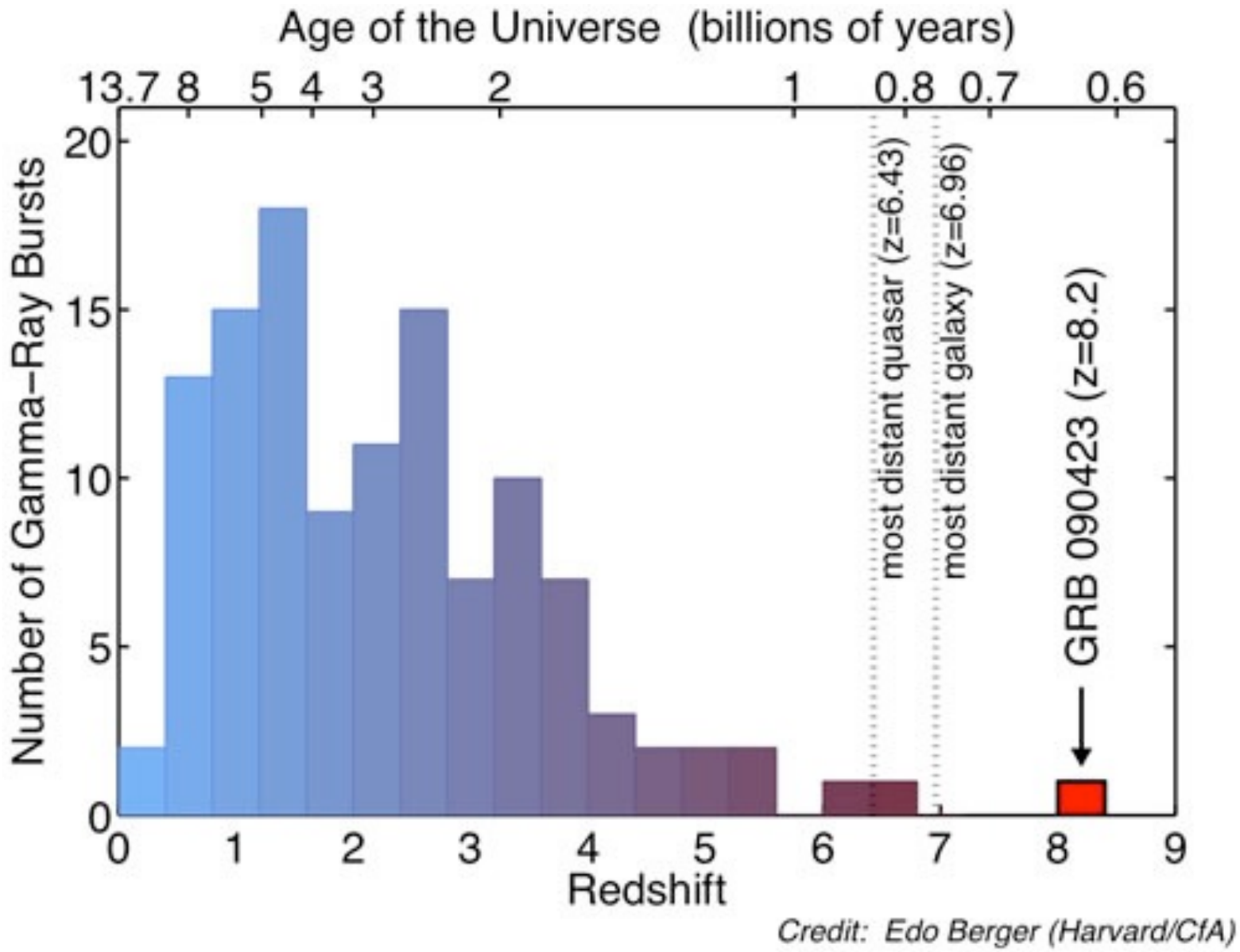
Do they look the same as other GRBs? Possible longer owing to more massive core?

Lower fraction end life as GRBs than Pop I/II of comparable mass



Single star fates: Heger et al. 2003

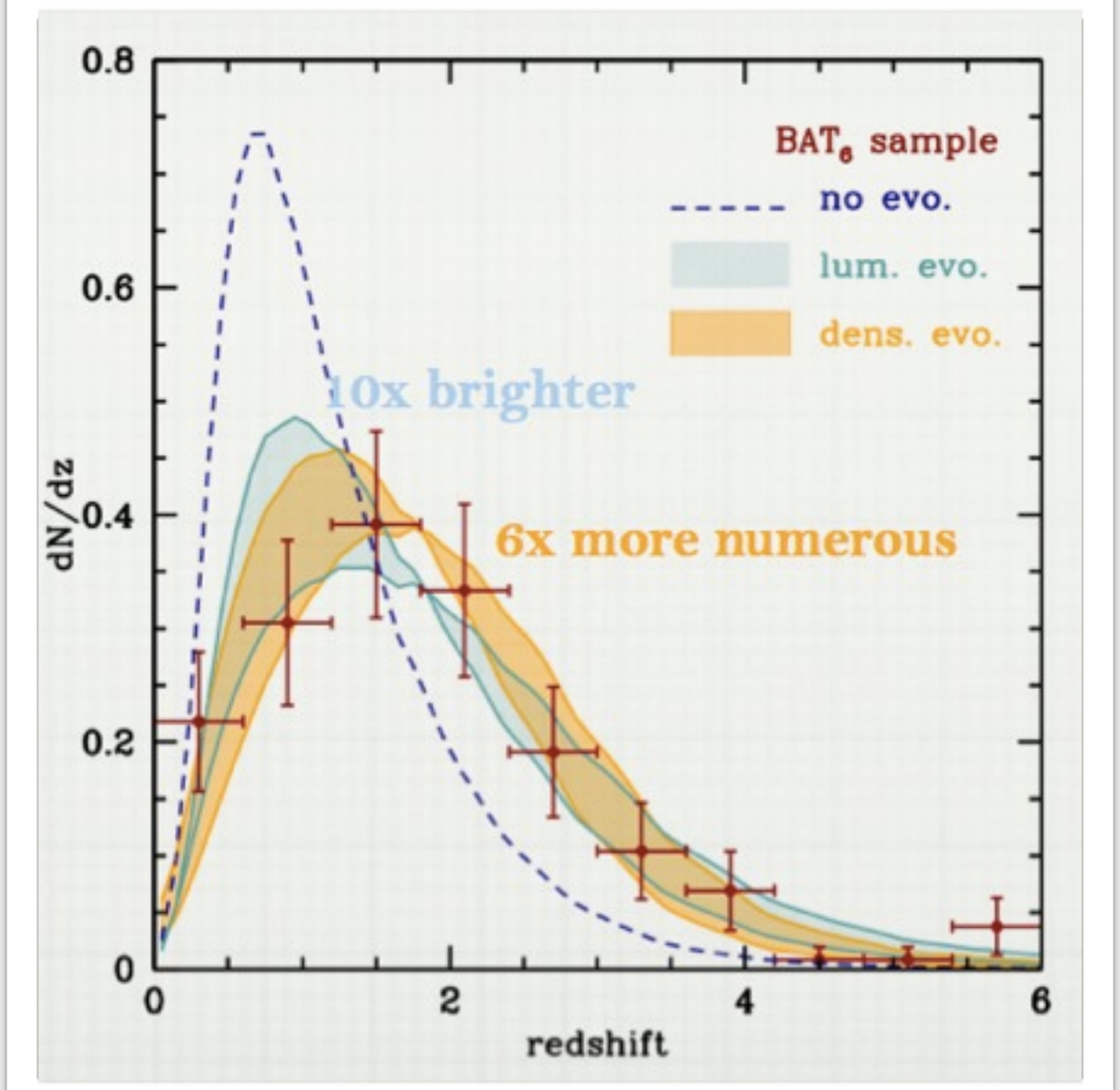
GRBs have been detected in small numbers out to high redshifts



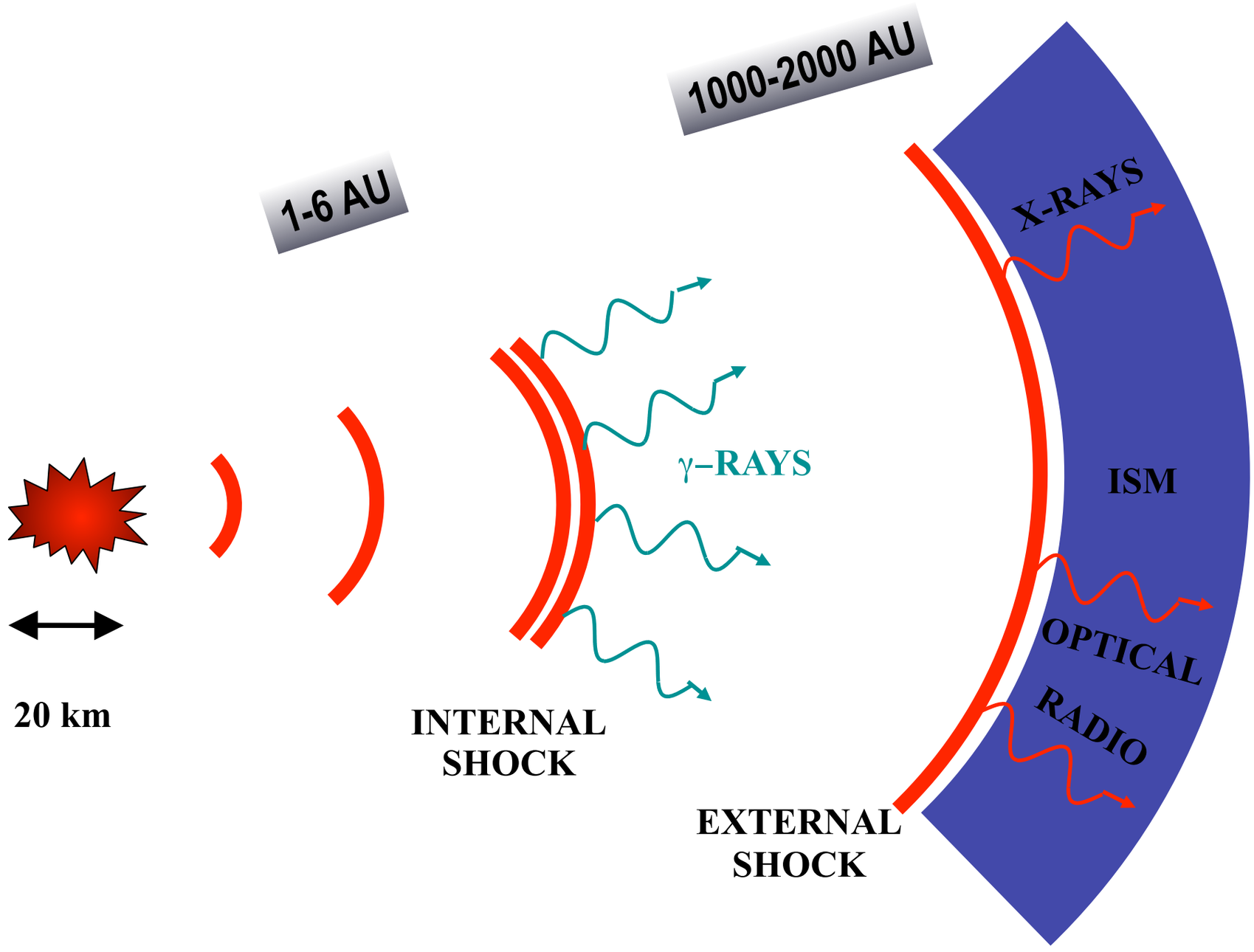
GRB 090429B at z=9.2 (photometric) is unconfirmed spectroscopically

GRB redshift distribution *may* indicate source number or luminosity evolution with redshift.

Salvaterra et al. 2012

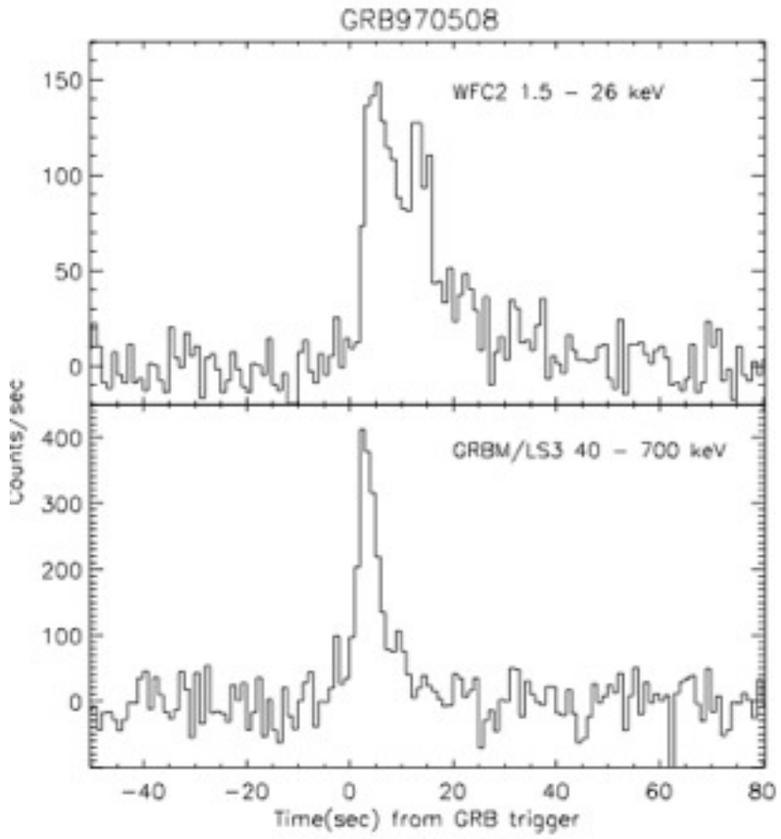


... but see Howell & Coward (2013) for alternative explanation

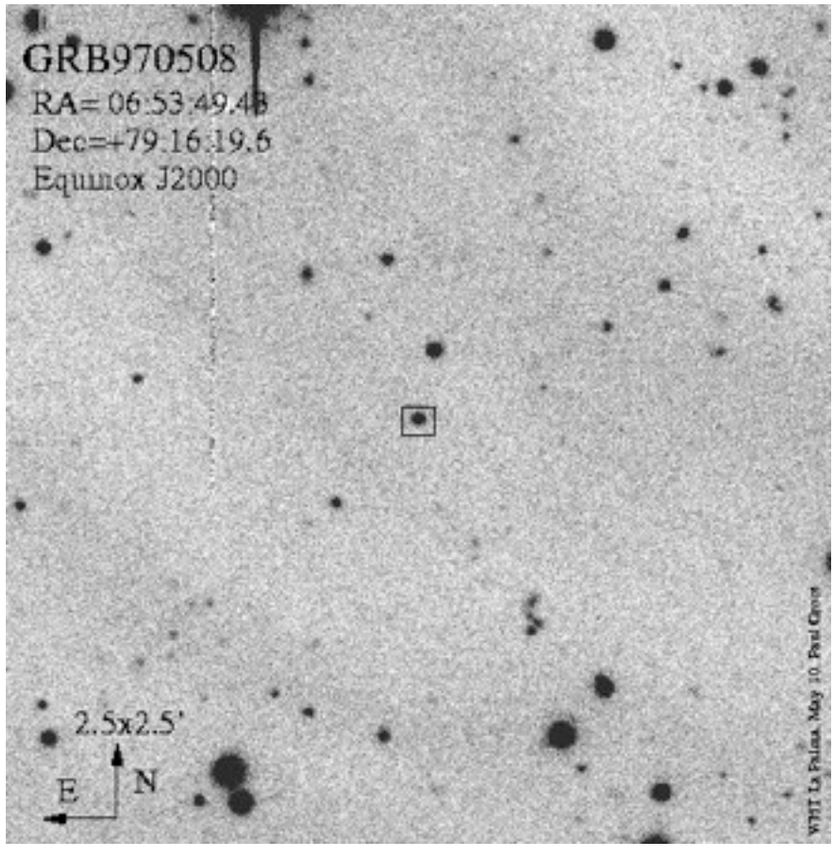


From Chuck Dermer

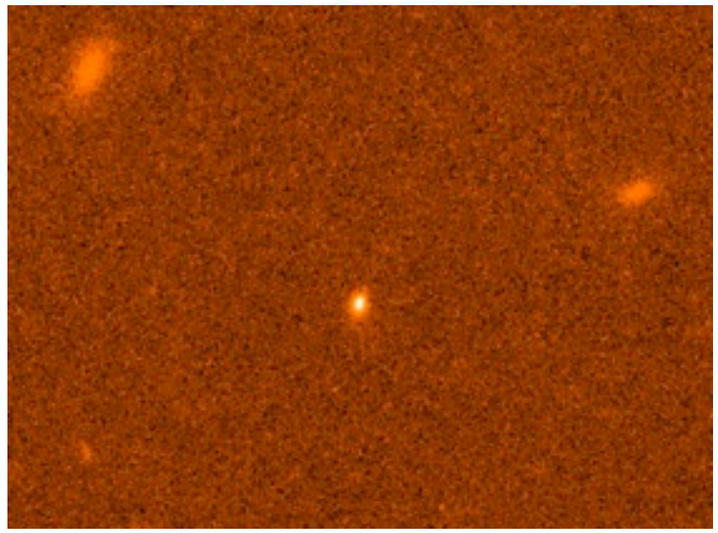
GRB 970508: the first GRB with known redshift, seen by BeppoSAX



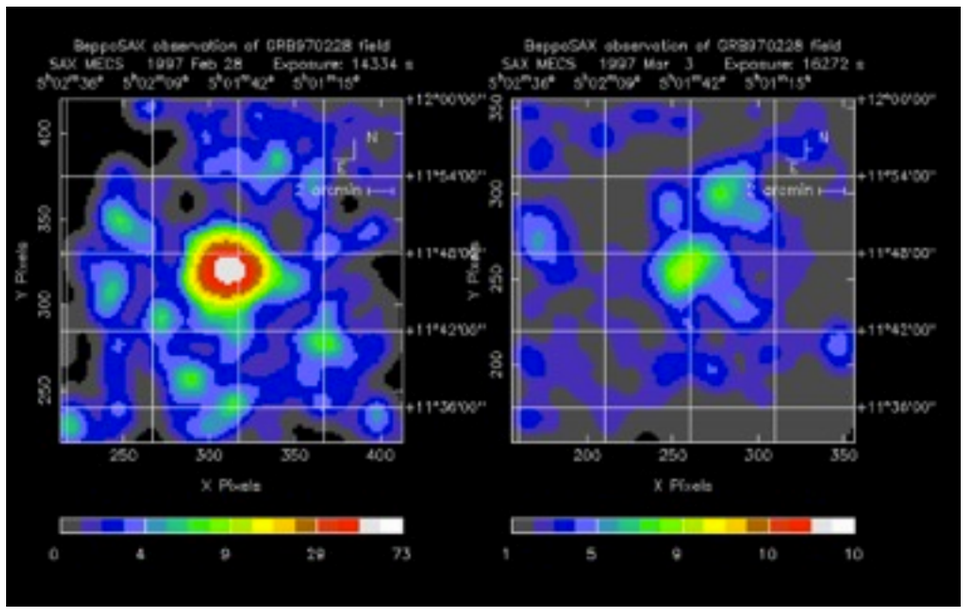
Piro et al. 1998

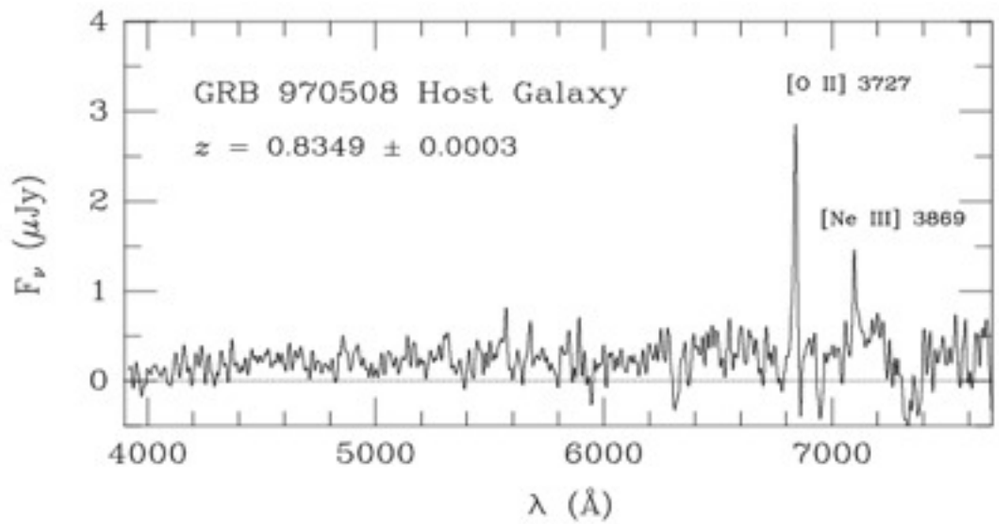


Bond et al., 1997; Galama et al. 1998

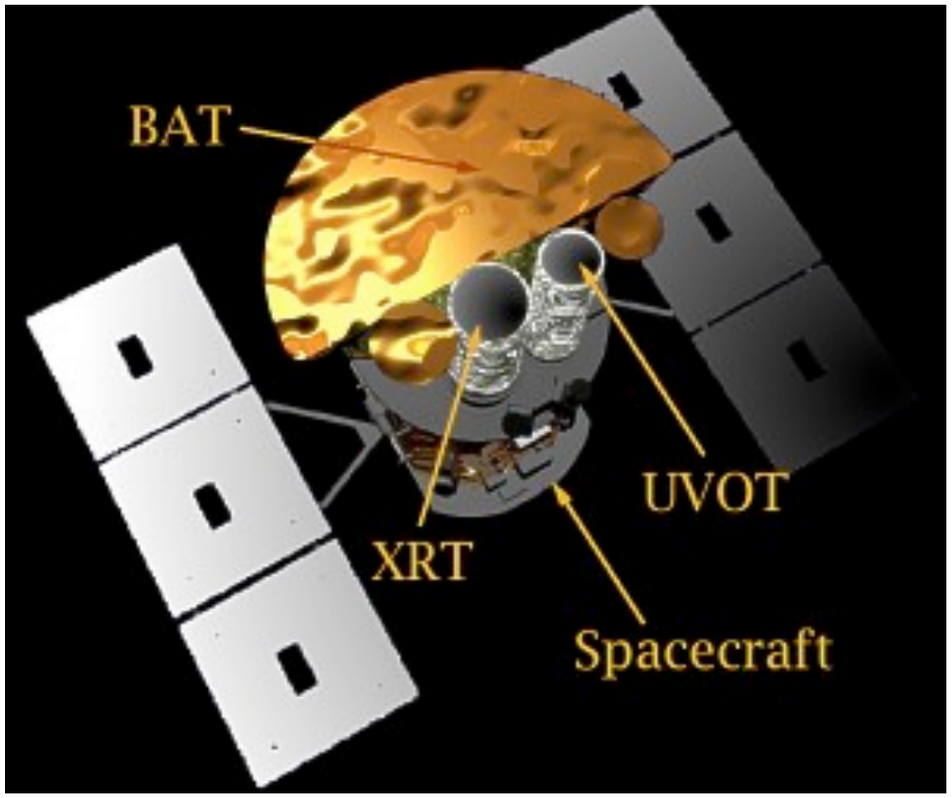


Fruchter et al. 2000; Bloom et al. 1998



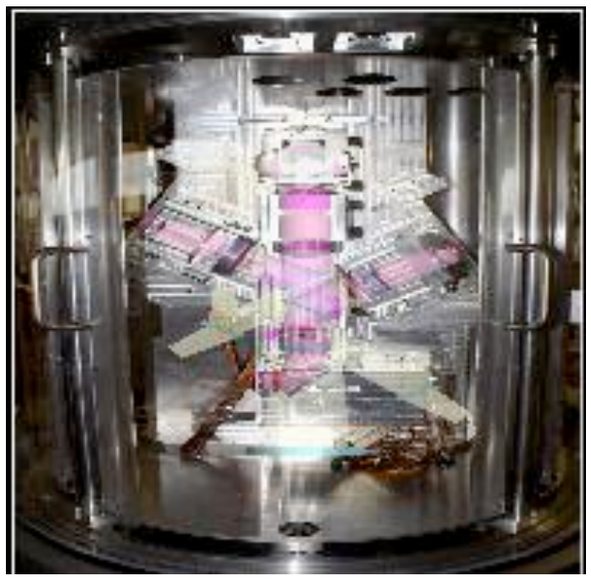


The Swift era (2004 - ?) : follow-ups are much faster



arcsecond position ~minutes after GRB

+



= redshifts for 1/3 of Swift-BAT GRBs, most through afterglow rather than host

Advantages of GRB afterglows as cosmic probes

- Unlike early galaxies, GRB afterglow luminosity not expected to be dimmer at dawn
- Afterglow identification allows pinpointing of host galaxies that would not otherwise be detected
- Afterglow spectrum featureless
- Afterglows are bright and act as backlight to probe host chemistry and history of reionization
- Possible probes of earliest cosmic magnetic fields?

Currently operating GRB instruments (other than Swift)

Fermi GBM + LAT
8 keV - 300 GeV
Broad sky coverage

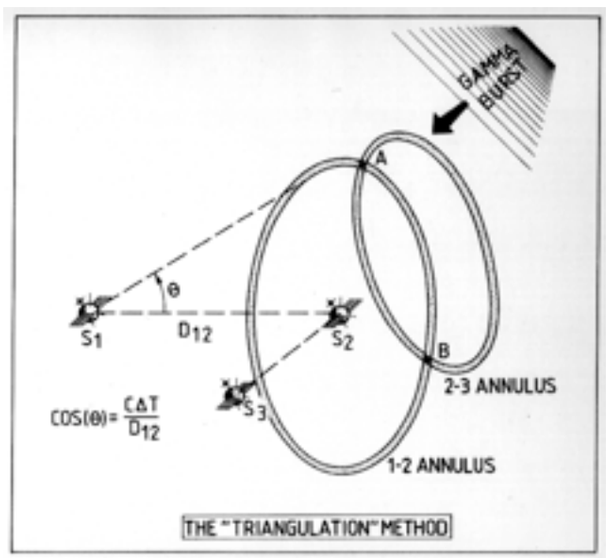
2008 - ?

INTEGRAL: very sensitive, low sky coverage

2002 - ?

+ CALET (2015 - ?)
+ AstroSat (2015 - ?)
(not dedicated GRB)

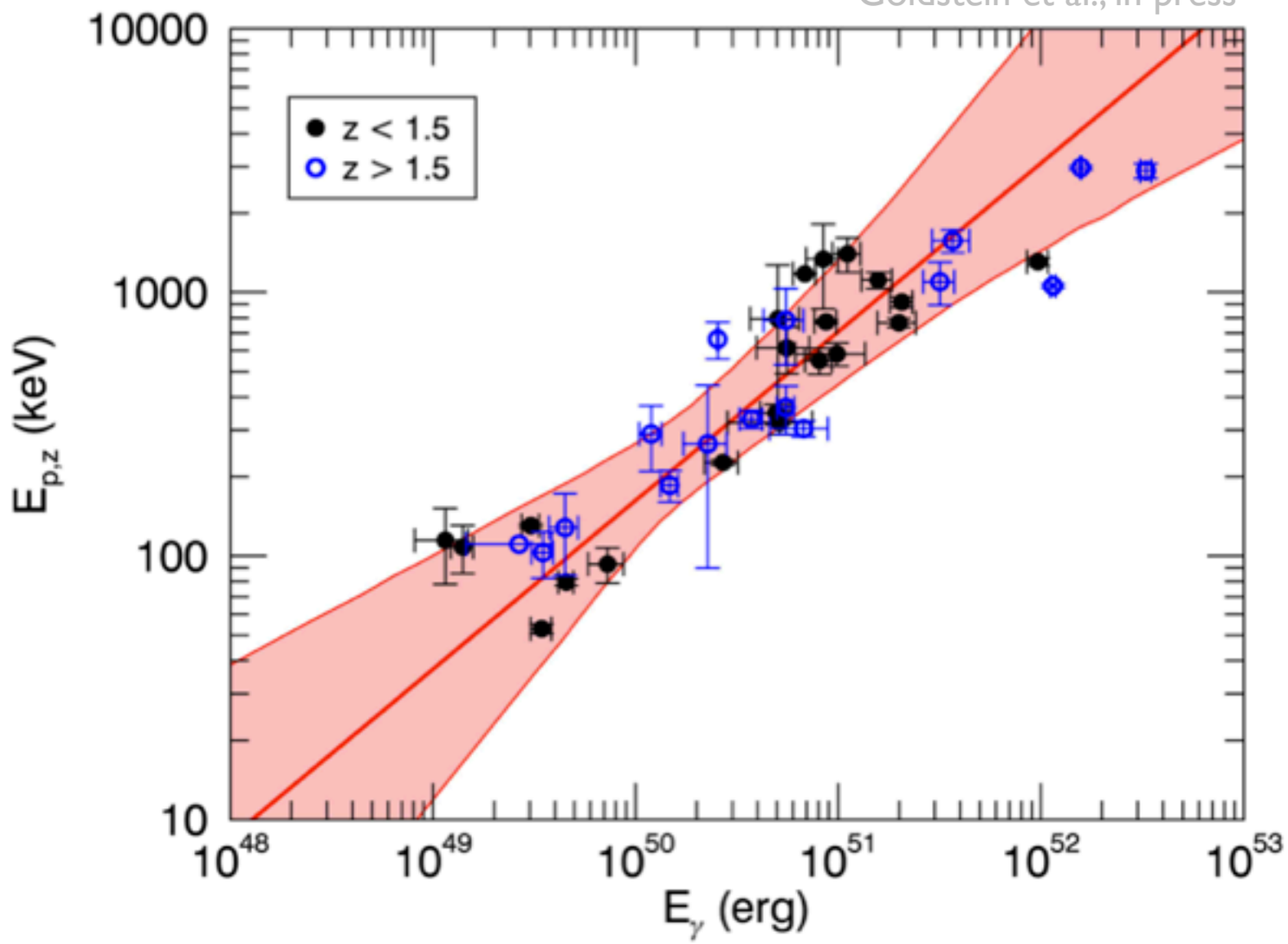
+ InterPlanetary Network



Can gamma-ray data enable GRBs to be like SN 1a in the distant universe?

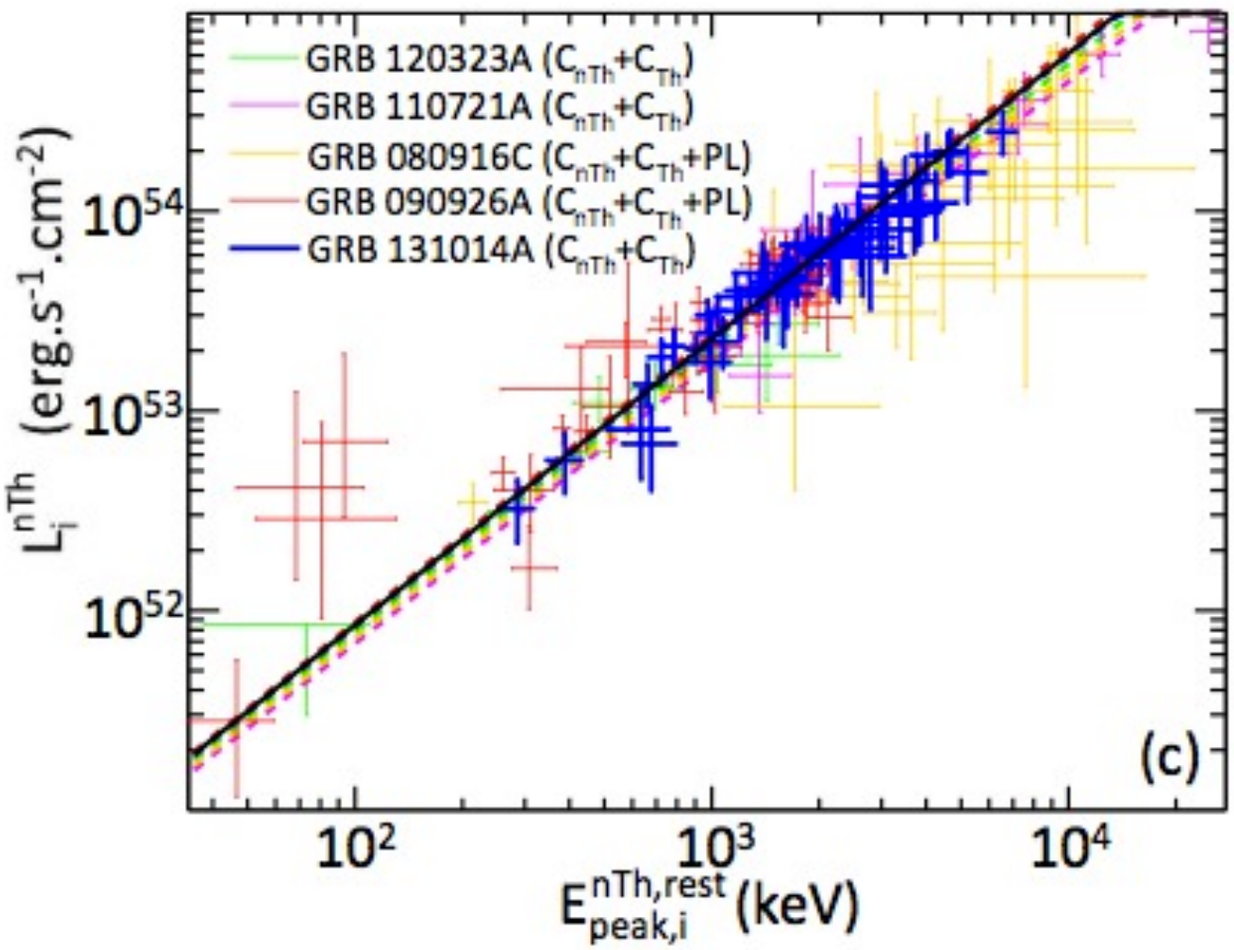
Relations (Liang, Amati, Ghirlanda, Yonetoku)
Physics and cosmology from (same authors, Levinson & Eichler, Guiriec, Goldstein)

Goldstein et al., in press



Spectral evolution of gamma-ray signal may provide independent measure of GRB redshift for bright GRBs with suitable time-dependent modeling

Guiriec et al. 2015

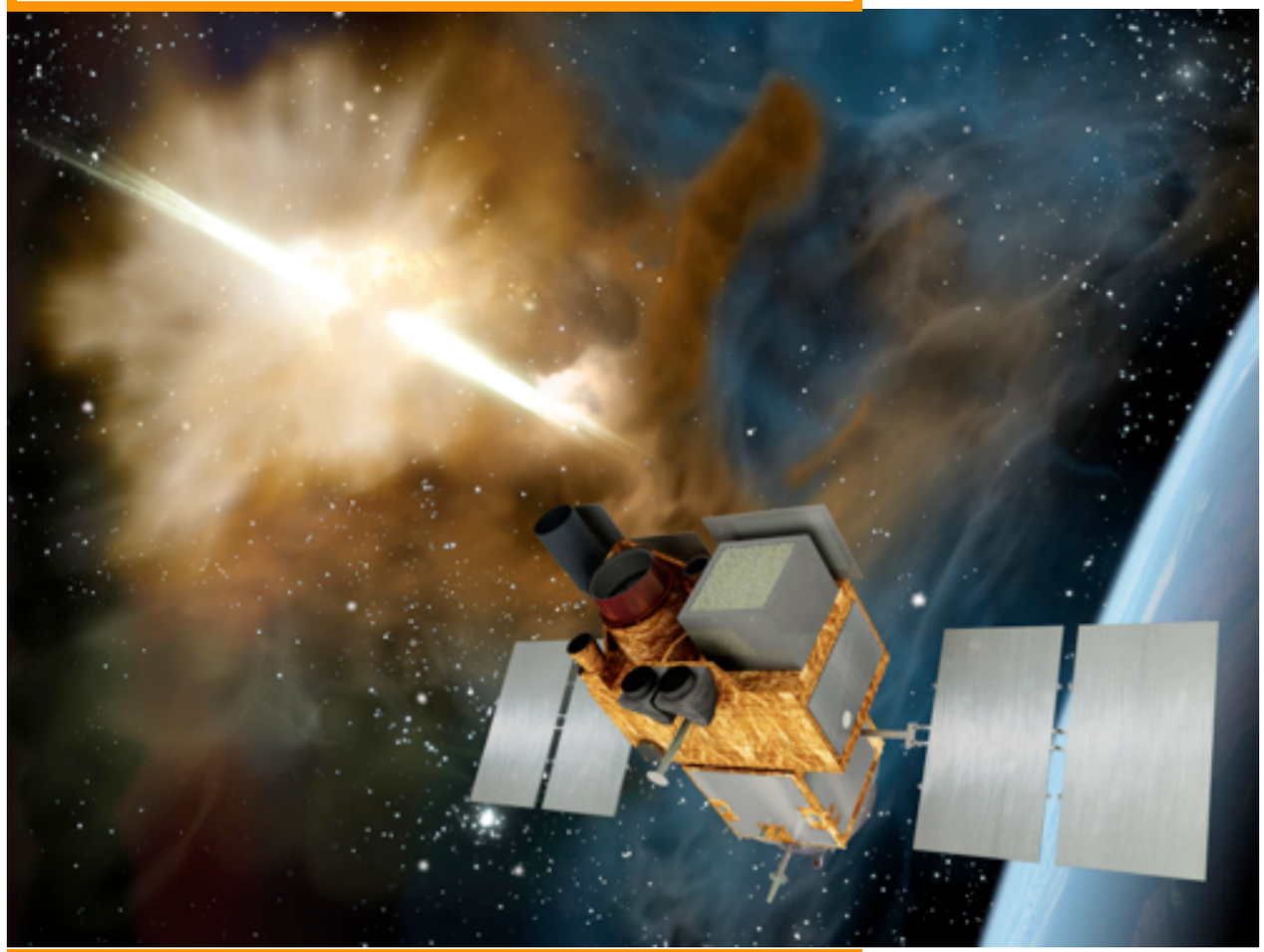


Can gamma-ray data help with cosmic dawn?

- Pair echoes at GeV/TeV can probe intergalactic magnetic fields at reionization epoch? (see, e.g., Takahashi et al. 2010)

Planned GRB instruments

SVOM: similar to Swift with ground segment to identify z>6



Launch n.e.t. 2022

+ MIRAX (Brazil)
+ Astro-H (Japan)

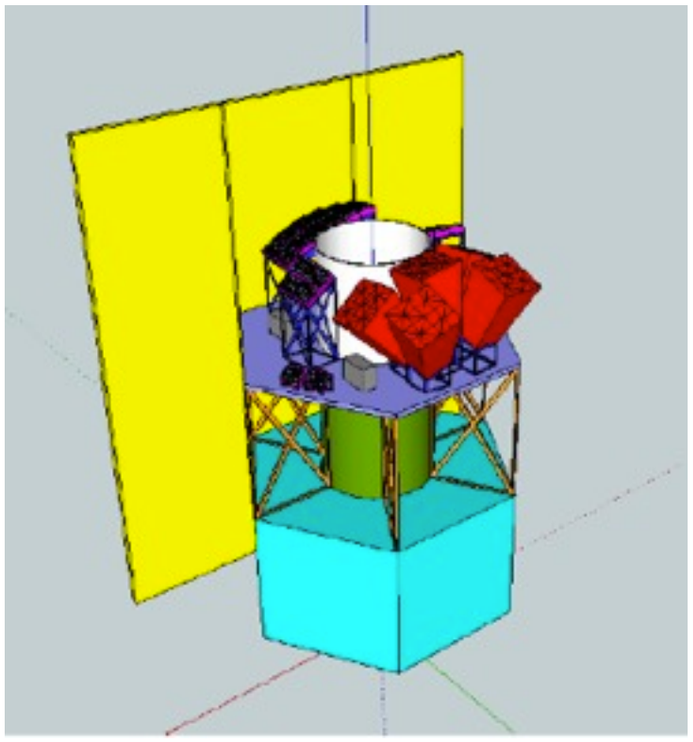
How do we improve our observations of GRBs as probes of cosmic dawn?
Need more redshifts for distant GRBs: sensitive detectors, broad sky coverage, fast redshift determination (IR)

- Proposed GRB concepts focus on high-z universe: wide-field X-ray detector for prompt emission detection + localization, follow-up with narrow-field IR instrument with crude spectroscopic capability for redshift (measure Lyman break), follow up for chemical history, host chemistry, UV, neutral H etc.

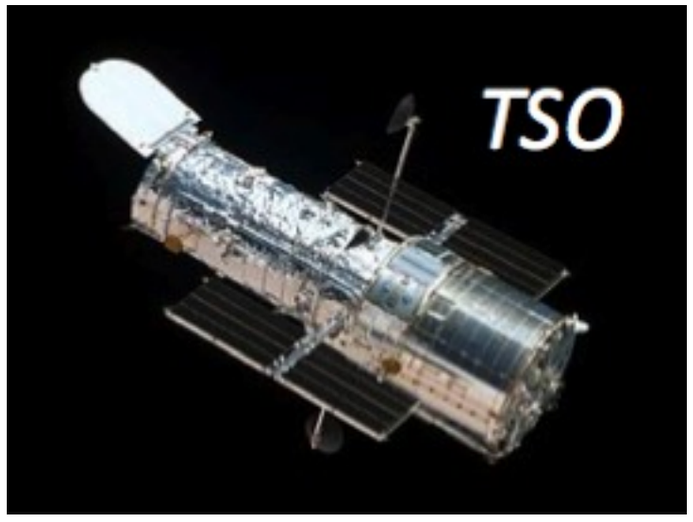
Probe-Class Mission Concepts:

JANUS (not selected)
NASA SMEX

Lobster (not selected)
NASA SMEX



THESEUS (not selected)
ESA M4 (tbd for M5)



+ Transient Spectroscopy Observatory (IR)

+ Transient Astrophysics Probe TAP (X-ray + IR)